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Dust Control In Coal Preparation and Mineral Processing Plants

By Edward F. Divers and Andrew B. Cecala

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Btu/h	British thermal unit per hour	hp	horsepower
cfm	cubic foot per minute	in	inch
ft	foot	in H_2O	in of water (pressure)
ft^3	cubic foot	mg/m^3	milligram per cubic meter
ft/min	foot per minute	min	minute
gpm	gallon per minute	pct	percent
h	hour	st/h	short ton per hour

DUST CONTROL IN COAL PREPARATION AND MINERAL PROCESSING PLANTS

By Edward F. Divers[1] and Andrew B. Cecala[1]

ABSTRACT

This U.S. Bureau of Mines report briefly evaluates the advantages and disadvantages of basic dust control techniques presently used by U.S. coal preparation and mineral processing plants. These include ventilation, baghouse-type collectors, wet scrubbers, electrostatic precipitators, source control, sprays, good housekeeping, and personal protection devices. Two specific problems in these types of operations are also considered: dust collector system duct clogging, and control room dust control.

Information provided in this report results from dust control research projects conducted by the Bureau at various coal preparation and mineral processing plants over the past decade to reduce workers' dust exposure. These studies indicate that plant ventilation systems normally provide the most cost effective method for dust control. Baghouses and scrubbers were also effective in specific applications, and examples of each are given. In extreme dust conditions, personal protection devices, such as respirators or the dust helmet, can also be highly cost effective.

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INTRODUCTION

Coal preparation and mineral processing plants can present a wide variety of dust problems. Fortunately, the problems in both types of plants can be reduced or resolved by the same basic techniques previously mentioned. This U.S. Bureau of Mines report provides information to operators considering various options for dust control. Its conclusions are primarily based on the field experience of Bureau personnel and plant operators and can be applied to most, if not all, plant dust problems.

BACKGROUND

COAL PREPARATION

There are approximately 500 coal preparation plants in the United States. The number of operators in each plant ranges from about 3 to 10 per shift; raw capacity ranges from roughly 250 to 1,250 st/h.

A recent Bureau survey of 21 coal preparation plants showed that one-third had highly localized respirable dust levels. These were dust levels in given specific areas of the plant and not exposure levels of plant personnel. No relationship was found between dust concentration and age or capacity of the plant. Some old plants show 1 mg/m^3 or less in all areas. Some new plants had respirable dust concentrations up to 11 mg/m^3 in specific areas. In general, these areas only had temporary occupancy, seldom exceeding several hours. High dust concentrations were closely associated with dry coal. With a few exceptions, these high dust concentrations were found in poorly ventilated areas on the ground floor. Excluding ventilation, few plants use operating dust control devices. Silica (quartz) analysis made on gravimetric samples from coal preparation plants show that the percent silica was usually below Federal limits.

MINERAL PROCESSING

There are well over 1,000 mineral processing plants in the United States. While dust concentrations in these plants are generally much lower than in coal preparation plants, the associated respiratory problem can be more severe due to silica. In recent years, Bureau studies have concentrated on those mineral processing plants having silica problems; the percent silica on gravimetric samples varies from 0 to over 90 pct. The problem can be especially severe in the silica sand industry where respirable silica usually is in the 80 to 90 pct range. When silica is present, the Federal dust standard is tightened below the usual 2 mg/m^3.

Unlike coal preparation, mineral processing plants usually process the product completely dry because of screen and duct clogging problems associated with wet products. When products are hygroscopic, the possibility for any type of wet processing is excluded. Another major difference is that many workers at mineral processing plants spend the majority of the workday at a specific location, which is not common in coal preparation plants. This can extend ventilation to year-round use, and fixed worker locations can be economically heated by infrared devices. Although they are not generally recommended due to costs, the use of steam, foams, and water additives (surfactants) may be appropriate for some mineral processing plants. Water sprays can also be an effective seasonal or occasional dry product (such as strip coal) control technique for both types of plants.

DUST SAMPLING INSTRUMENTS

Two types of dust sampling equipment were used during these evaluations: gravimetric dust samplers and/or instantaneous dust monitors called real-time aerosol monitors (RAM) (*1*).[2]

Gravimetric dust samples have been the primary means of determining respirable dust concentrations used by the Mine Safety and Health Administration (MSHA) since dust monitoring became a mandated practice as established by the 1969 Federal Mine Health and Safety Act. Although gravimetric sampling is performed for all compliance testing, it is not the most advantageous technique for many studies because of the time required to obtain dust data.

The instantaneous RAM-1 dust monitor built by Monitoring Instruments for the Environment (MIE), Inc., Bedford, MA overcomes the drawbacks of gravimetric sampling. The RAM-1 unit instantaneously calculates respirable dust concentrations. However, the RAM-1 cannot distinguish the quartz concentration of the dust.

Visual observation can be an effective technique for estimating dust concentrations, even though water mist can cause problems. As a general guideline, respirable dust concentrations below 2 mg/m^3 will not create visibility problems or haloing around lights; these are especially

[2]Italic numbers in parentheses refer to items in the list of references at the end of this report.

evident above 5 or 6 mg/m^3. Visibility problems beyond 50 or 60 ft typically start at 8 to 10 mg/m^3, and distinct visibility problems beyond 20 to 30 ft occur above 15 or 20 mg/m^3. At these high respirable concentrations, coal dust odor can be detected and rapid accumulation of all types of larger dust particles on most surfaces is evident.

VENTILATION

WHOLE PLANT

Ventilation can be an excellent low-cost dust control technique for all plants during mild weather. Plants using effective ventilation systems have low dust concentrations, with peaks generally below 2 mg/m^3 respirable. These systems consists of powered exhaustors (fans) or gravity ventilators in the roof, open access doors, and open-close-type wall louvers at grade. Due to a slight increase in initial plant costs, ventilation systems are not built into most plants. However, since ductwork is not required, subsequent addition of a ventilation system can be relatively inexpensive, about $1 per cubic foot per minute for a powered roof exhaustor system with adjustable louvers at grade. Powered roof exhaustors should be sized to provide between 6 to 12 air changes per hour. Where dust concentrations are known or safely assumed to be low, 6 to 8 air changes per hour can be used.

$$\text{Air changes per hour} = \frac{\text{Total volume exhausted per hour}}{\text{Total volume of ventilated building}}$$

However, long-term, high dust concentrations, above 6 mg/m^3, may not be adequately controlled by ventilation alone. In these cases, primary efforts should be directed to control at the dust source, or using dust collectors such as baghouses or scrubbers.

Design guidelines for the installation of plant ventilation systems can be found in the "ASHRAE Handbook of Fundamentals" or their systems handbook published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., Atlanta, GA, or "Industrial Ventilation" published by the Committee on Industrial Ventilation, Cincinnati, OH.

For ventilation to be effective as a dust control technique, it is critical that the design be capable of supplying relatively clean makeup air to the system. If air supplied to the ventilation system is contaminated, the ventilation system can be ineffective and may increase a worker's dust exposure. This occurred at a mineral processing plant where trailer trucks were being bulk-loaded outside a mill building (fig. 1). The dusty air generated from the bulk-loading process was drawn into the mill as makeup air for a ventilation system; worker's dust exposure was increased 147 pct over previous (normal) levels during the bulk-loading. Inlet louvers should not be placed near outside dust or other contaminant sources.

LOCAL EXHAUST

Local exhaust through wall exhaustors, fans, and other devices can be a highly cost-effective technique for removing dust from specific, generally small, areas. This is frequently done with wall-mounted propeller fans properly protected and mounted close to the dust source, usually without ductwork (fig. 2). Fan volumetric capacities generally range from 10,000 to 25,000 cfm or more, with motors from 1 to 5 hp. The exhaustors are controlled by operation of the dust-generating source, such as a crusher, and/or manual control. Because strong outside winds can negatively affect the performance of exhaustors, their placement should normally be on the nonwindward (lee) side of buildings.

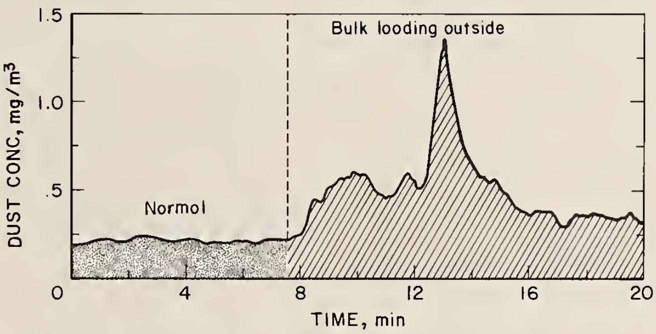

Figure 1.–Effects of bulk-loading outside on worker's exposure inside mill.

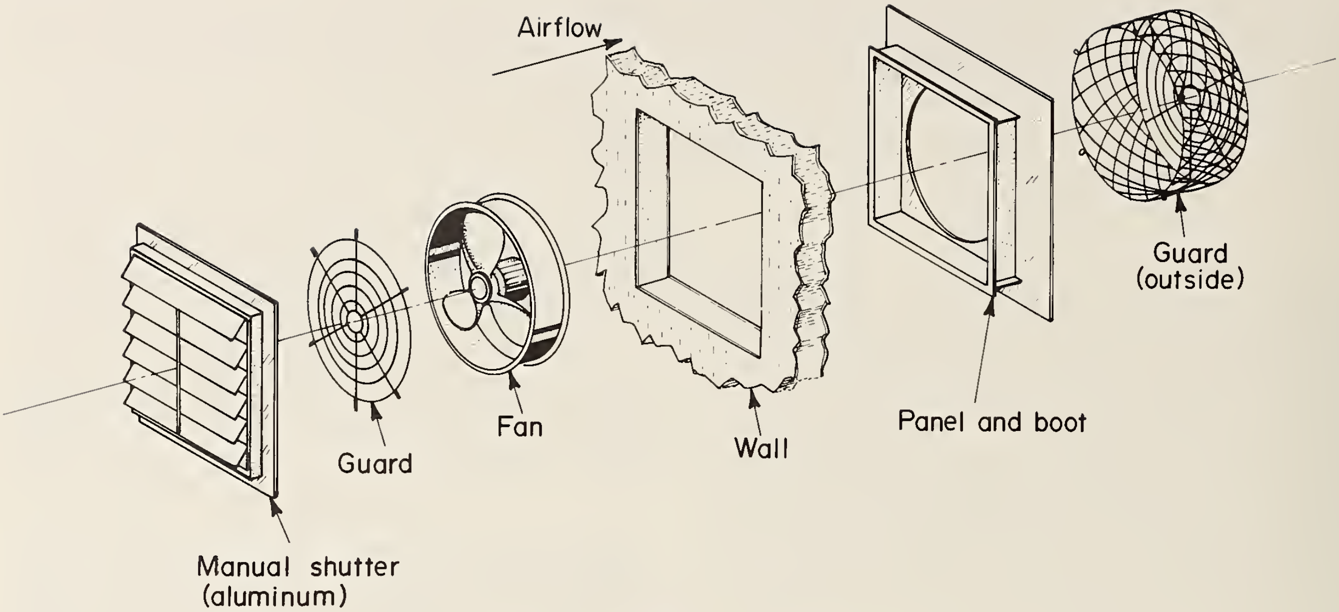

Figure 2.-Wall exhaustor—typical layout.

AIR CLEANERS

BAGHOUSE-TYPE DUST COLLECTORS

Baghouses collect airborne dust by filtration through special cloths, somewhat similar to a home vacuum sweeper. The collected dust is normally shaken automatically from the filters into a hopper (fig. 3). Baghouses have several advantages, especially for mineral processing plants: they offer high dust collection efficiency that is essentially independent of mineral type, and they do not use water. When in-plant space is not available, outside installations are generally successful. Disadvantages are size (especially height), duct routing and cost, handling of the collected dust, and frequent problems when excessive moisture or water is in the air. Initial cost generally exceeds $4 per cubic foot per minute. Nevertheless, baghouses are especially recommended for those plants on a reduced silica standard. Where very high dust collection efficiency is required, use a baghouse.

Visible dust in the exhaust plume always indicates problems in baghouse systems. For example, at one coal preparation plant a 38,000 cfm outside unit discharged to the atmosphere. A visible plume was emitted from its exhaust and respirable dust sampling showed a concentration of 5.0 mg/m^3. This was caused by torn bags. Properly designed and maintained systems will show less than 1 mg/m^3 in the exhaust plume, and no visible dust.

Another baghouse system was located on the second floor of a 5-year old plant. Its capacity was approximately 15,000 cfm, and it also exhausted to the outside. A simple manually operated splitter was installed in the fan discharge duct that also allowed inside discharge during cold weather. Since the system was adequately maintained, exhaust concentrations averaged 0.70 mg/m^3. Inside discharge during severe cold weather saved over 1 million Btu/h by reducing makeup air heating cost. Inside discharge should not be used when silica dust is present.

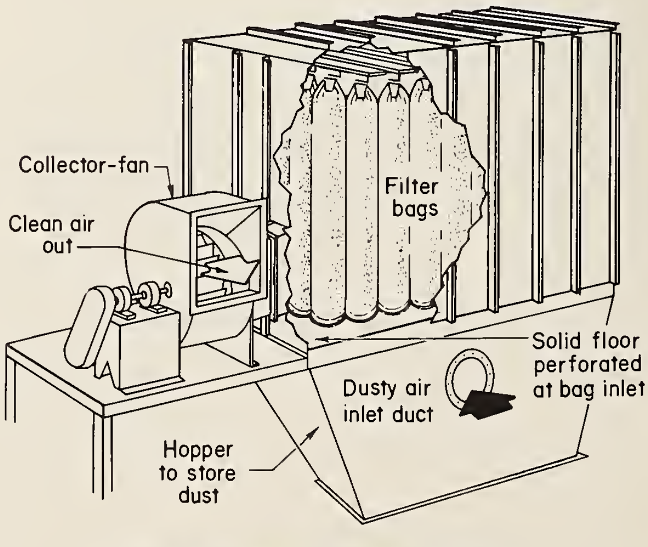

Figure 3.-Baghouse-type dust collector.

Silica dust presents a serious dust hazard and requires the plant to meet a lower Federal dust standard.

Baghouses can achieve very high respirable dust collection efficiency, well above 99 pct with special bag filter material. This high efficiency cannot be readily achieved by scrubbers. However, scrubber efficiency can be adequate for most coal preparation applications.

SCRUBBERS

Scrubbers frequently offer another practical control method, especially for coal preparation plant dust control. They collect airborne dust by highly turbulent collision with water droplets or a wetted surface, the water then being separated from the airstream. The water consumed does not present problems to most coal preparation plant operators, but can make them unsuitable for minerals processing. Dust collector efficiency can be sufficient to allow the scrubbed air to be discharged back into the plant, and they are small enough to allow them to be retrofitted into operating plants. Typical components consist of a 25,000 to 50,000 cfm fan generally operating between 6 to 10 in H_2O, the scrubbing device, water sprays at a flow rate between 0.5 and 3 gpm per 1,000 cfm of airflow, a water droplet eliminator and duct work to various dust sources. Initial costs are $2 to $3 per cubic foot per minute, and maintenance is uncomplicated.

Disadvantages are fan power cost and fan noise, potential clogging, and cold weather freezing problems.

Three commonly used types of scrubbers were evaluated for this work: the small-diameter cyclone (fig. 4), the flooded bed (fig. 5), and the venturi (fig. 6) (*2*). The primary purpose was to determine if the cleaned air could be safely discharged back into the plant.

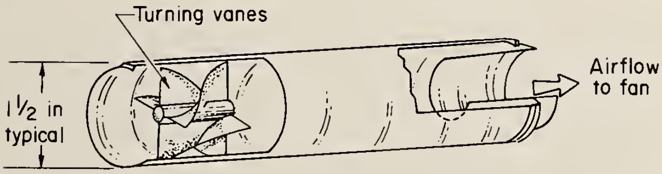

Figure 4.–Small-diameter cyclone type scrubber.

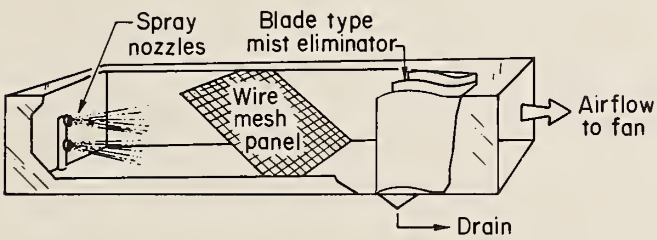

Figure 5.–Flooded fibrous bed-type scrubber.

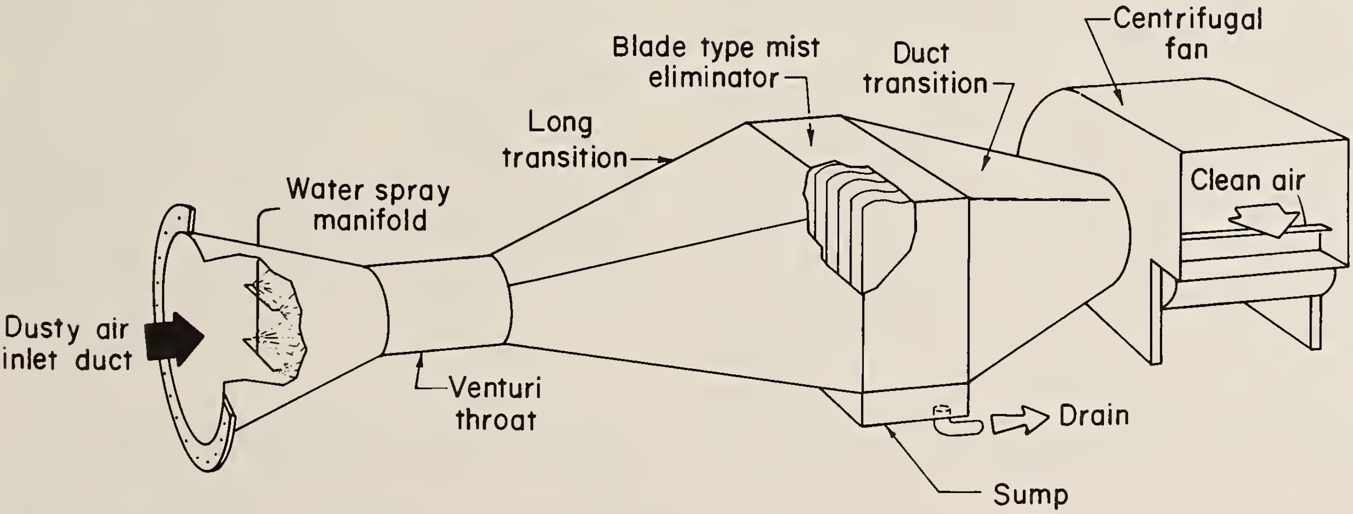

Figure 6.–Venturi-type scrubber—horizontal arrangement.

Dust sampling results showed that all three can do an adequate job of dust control at the pickup locations. Results at the vicinity of the scrubber fan discharge were determined (table 1).

Table 1.–Respirable dust test results[1]

(8-h gravimetric averages at scrubber)

Scrubber type	Discharge, mg/m^3	Efficiency, pct
Small-diameter cyclone	2.47	88
Flooded fibrous bed	1.12	95
Venturi	3.09	85

[1]Inlet was 21 for all three types of scrubbers.

The flooded bed scrubber was more than twice as efficient as the small-diameter cyclone, allowing unlimited exposure time. The results are consistent with previous Bureau studies comparing both scrubber types (*3-4*). However, both scrubbers clogged with coal particles, creating unacceptable maintenance problems. Air pressure drop across the flooded bed panel increased from 3.8 to 6.5 in of water during 9 h of typical operation due to clogging. The cyclone panel increased about half of this 2.7 in rise, i.e., 1.37 in, under identical conditions. Proper operation of these scrubbers is highly dependent upon a steady and uniform application of spray water. Clogged and partly clogged sprays decrease the dust collection efficiency, and increase the pressure buildup across both cyclone and flooded bed types.

Analysis of the used flooded bed panels showed that clogging was primarily caused by large particulate (up to 1/16-in) embedded in the mesh. This indicates that the dust inlet duct was located too close to the dust source. In most underground applications, the flooded bed panels are cleaned once per shift by drying and shaking, or by direct flushing with a hose.

The venturi showed no indication of clogging. Its efficiency was limited by the fan pressure capability in this installation that only allowed a maximum of 6 in H_2O gauge differential pressure across the venturi throat. The dust collection efficiency of a venturi scrubber is essentially unlimited, and primarily dependent on fan pressure capability and waterflow rate. Past Bureau work shows that a throat differential above 10 in H_2O gauge would keep discharge concentrations below 2 mg/m^3 in this installation (*3*).

Owing to its simplicity and low cost, venturi-type scrubbers can be readily recommended for coal preparation plants. They are commercially available in a wide range of configurations, including vertical (fig. 7). As a guideline, minimum throat differential pressures should be 6, 10, and 15 in H_2O gauge for respective inlet concentrations of 10, 20, and 30 mg/m^3 respirable dust. A venturi should not be operated at less than 4 in H_2O gauge pressure drop across the throat.

ELECTROSTATIC PRECIPITATORS

Electrostatic precipitators (*5*) pass airborne dust between electrically charged plates (fig. 8). This causes the dust to migrate toward and adhere to the plates; this dust is then automatically shaken or washed from the plates. Precipitators offer several advantages, including very-high dust collection efficiency, and very-low air pressure drop (1/2-in H_2O gauge across the precipitator). This results in low fan power requirements. Initial, $1 to $1.50 per cubic foot per minute, and operating costs are lower than scrubbers or baghouses.

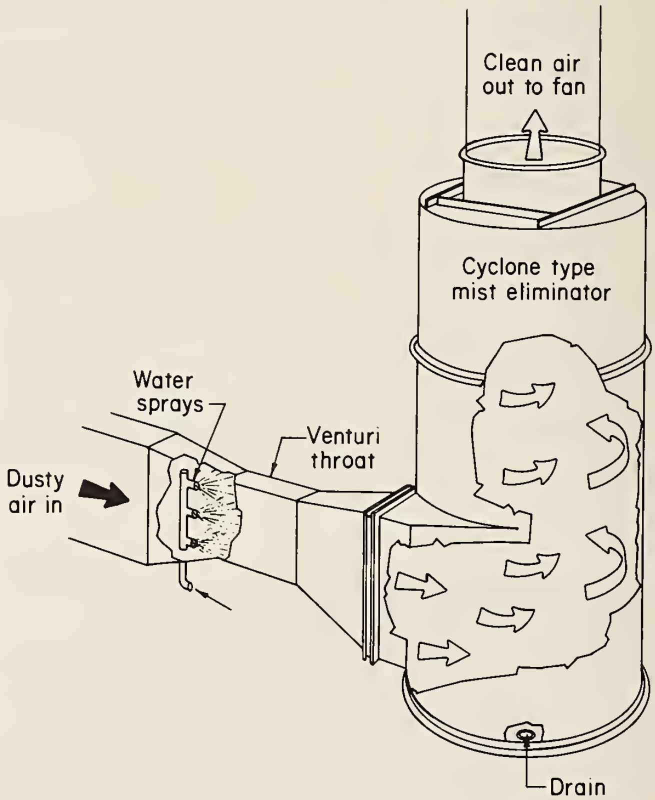

Figure 7.–Venturi-type scrubber—vertical arrangement.

Disadvantages include fairly large in size, and a requirement for relatively experienced maintenance personnel to work with the high voltages, and potential sparking problems associated with high voltages. Efficiency is reduced if subjected to vibration, if inlet air velocity is not uniform, and if shutdown time is required for cleaning. Detergent water is frequently required for cleaning.

Results of efficiency tests of electrostatic precipitators showed a wide efficiency difference between various plants. One 5,000 cfm installation was only 30 pct efficient on respirable coal dust. Minerals containing sodium can also present problems when high dust collection efficiency is required. For best results, electrostatic efficiency data on the specific dust and installation should be obtained before purchasing a precipitator.

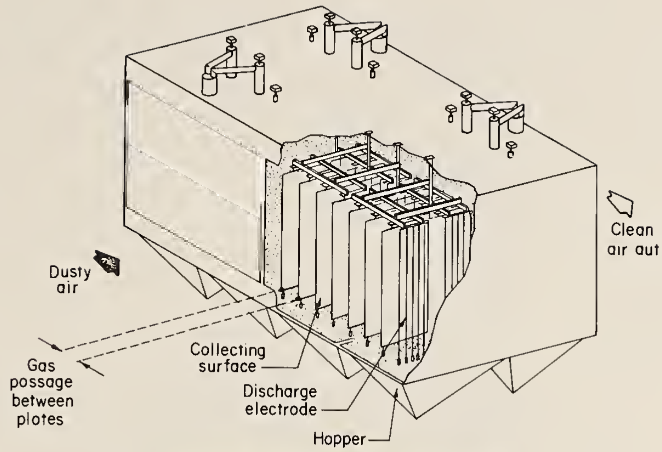

Figure 8.–Electrostatic precipitator.

CONTROL AT SOURCE

For maximum cost effectiveness, dust should be controlled at its source prior to dilution and dispersal. Usually, dust sources are determined by visual observation, especially during startup or on-off procedures. Precise determination of the appropriate control technique depends on many factors, some beyond the scope of this report. However, these general guidelines should be followed:

* A thorough dust survey should be conducted when it appears that control costs will be significant.
* The survey should at least determine the dust type (if unknown), its sources, extent, and concentration.
* The control technique should be primarily based on survey data. For example, simple ventilation may be suitable for a dust concentration of 4 mg/m^3, but not for 10 mg/m^3.

Although not pointed out in most literature, high dust concentrations or low threshold limit value (TLV) usually require more severe and costly controls, such as baghouses or scrubbers. Frequently, two control techniques such as water sprays and ventilation can work together for maximum cost effectiveness.

WATER SPRAYS

Where the product allows, water sprays can be very cost effective for dust source control (*6-7*). Their primary effectiveness is in keeping the dust from becoming airborne, accordingly the effectiveness is primarily dependent on flow rate and coverage, not water pressure. Once airborne, respirable dust is very difficult to knock down. This knockdown effectiveness *is* dependent on flow rate and pressure, and the best spray systems seldom exceed 60 pct efficiency on respirable dust. Although not generally recommended due to cost, water additives (surfactants) (*8*), foams (*9*), and steam (*10*) can occasionally provide additional source control.

GOOD HOUSEKEEPING

Effective housekeeping is essential for maintaining acceptable dust levels. Product material allowed to buildup on the walls, beams, equipment, floors, and walkways can be readily dispersed. Dust buildup on grated floors and walkways is a significant dust contributor, especially with the higher floor levels; a worker can create a significant amount of dust just walking across this grating, causing dust to drop three or four floors. An effective housekeeping practice is to clean the mill or plant at least once a day. Many operations will wash down all floors and equipment to achieve this, although in some plants that do not allow for the use of water, vacuum cleaning systems are used. Sweeping or blowing clean air with compressed air should not be used. Figure 9 shows the increase in the respirable dust exposure to a worker when a co-worker in a mill was sweeping the floor one level below with a push broom. The operator's dust exposure increased to nearly six times the previous concentration because of this dust.

Plants or mills with low dust concentrations generally had good housekeeping practices. Most of these operations would wash down or vacuum the plant or mill each shift. This is not to suggest that effective housekeeping was the sole reason for low dust concentrations, but to emphasize that those operations who were trying to maintain low dust levels realized the importance of this practice. Various types of commercial vacuum cleaning devices are available for this purpose. They range from high capacity remote vacuum collectors (fig. 10) to easily portable tank-type units.

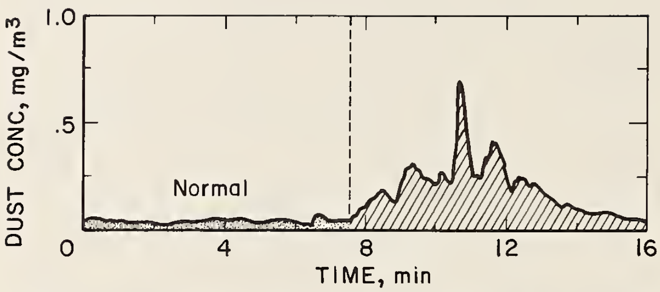

Figure 9.–Increase in worker's dust exposure from broom sweeping.

Figure 10.–High capacity remote vacuum system.

PERSONAL PROTECTION DEVICES

Occasionally, dust control with baghouses or scrubbers may not be practical, as from various sources spread over large areas. In these cases, control at the dust sources is suggested. Where this is prohibitive due to costs, space limitations, or other reasons, use of the dust helmet or other personal protection devices such as respirators is strongly recommended.

DUST HELMETS

Dust helmets have been designed to provide dust protection for the wearer without some of the talking, spitting, and fit problems associated with typical respirators. They use a small fan in the helmet to provide filtered air to the breathing zone of the wearer (fig. 11). The fan is powered by a rechargeable belt-mounted battery suitable for 8-h continuous operation. A high efficiency filter is fitted to the fan discharge, a coarse filter at its inlet; both are throw-away types. The helmet is used with a full-face lucite lens. Tests of the helmet's efficiency on various dusts and conditions generally show excellent results and reasonably good acceptance by personnel, except when they must work in tight places. Various types of side shields are available to increase the helmet's dust protection efficiency as ambient air velocity rises. Bureau tests of the helmet with two types of side shields show dust reductions greater than 90 pct between ambient and inside helmet respirable concentrations (*11*). Typical in-plant tests would show 92 pct without a full-face side shield, and 98 pct with.

The helmet can be very useful in extreme dust conditions, such as in coal preparation plants with high respirable concentrations or in mineral processing plants

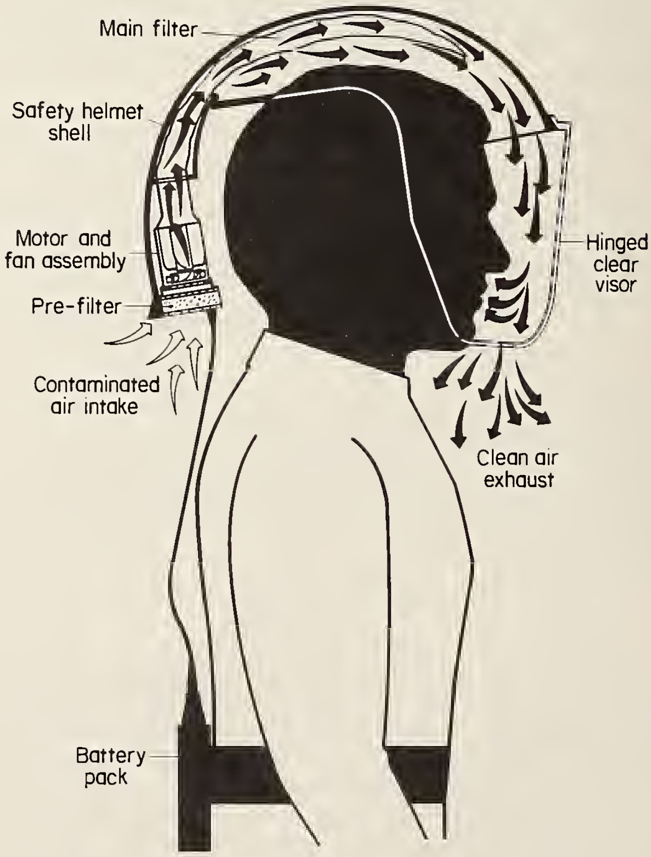

Figure 11.–Dust helmet.

Figure 12.–Disposable-type respirator.

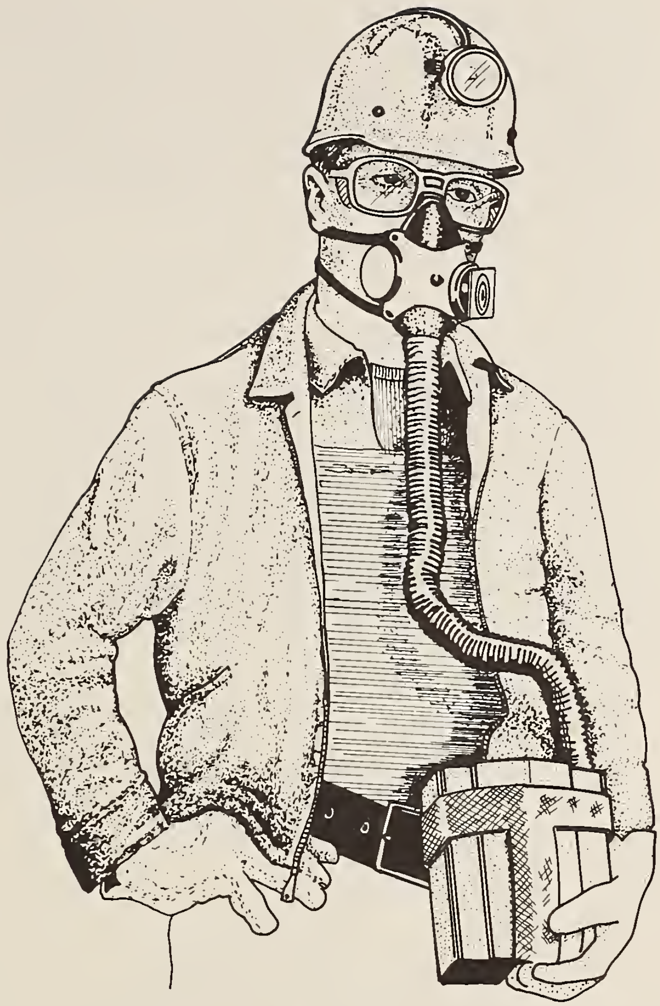

Figure 13.–Positive pressure-type respirator.

with high silica dust levels. Primary disadvantages are glare from the lens, especially for those who must wear glasses, and the excessive bulk for tight work spaces.

RESPIRATORS

Many types of dust respirators are also commercially available for this use. Dust protection efficiency is roughly dependent on cost, type, face fit, and ranges from approximately 60 pct for simple throw-away or negative-pressure types (fig. 12), to the upper 90 pct for powered positive-pressure types (fig. 13). When respirable silica dust concentrations exceed 5 mg/m^3, or long-term exposure is anticipated, the latter types should be used. However, dust helmets and respirators only help protect the worker from usual dust and mist, they are not to be used for harmful chemical dusts or gasses.

SPECIAL PROBLEMS

PIPE AND DUCT CLOGGING

Serious duct clogging problems occur in some of the duct collector systems in coal preparation plants; dust particles gradually accumulate in the horizontal duct runs between the pickup points and fan, and almost completely block the airflow. This not only cripples the performance of the duct collector system, but also presents safety problems. The added weight of the dust can occasionally break the duct hangers, allowing sections to drop. Clogging could occur as often as every 6 months. In these cases, the preparation plant operators would occasionally drop these duct sections and flush with high-pressure water. The common remedy for this problem is to maintain an adequate duct air velocity as indicated in the American Conference of Government-Industrial Hygienist (ACGIH) Handbook, however, the duct air velocity in some plants is already above 4,000 ft/min. Conversations with material handling experts show that these problems are not rare, even in high-velocity systems. No simple solution has been found to the duct clogging problem. One possibility has been to paint the duct interior, first with an epoxy nonlift primer followed by an epoxy topcoat, both with suitable catalyst. Extra water sprays in the duct sections that clog have also been successful. In some cases, a dropout box or inertial separator can help. Use of inertial separators can also help prevent scrubber clogging. Inertial separators separate large dust particulate

from the airstream using a centrifugal, gravitational, or inertial force. The separate dust falls into a hopper, where it is temporarily stored. The three primary types are settling chambers, baffle chambers, and centrifugal collectors. Neither settling chambers nor baffle chambers are commonly used in the minerals processing industry, mostly due to space requirements, and difficulties with cleaning and disposal of the collected dust.

Settling chambers (fig. 14) consist of a large box installed in the ductwork. The sudden enlargement at the chamber reduces the speed of the dust-filled airstream, and heavier particles settle out. They are simple in design and can be readily manufactured.

Baffle chambers (fig. 15) use a fixed baffle plate that causes the airstream to make a sudden change of direction. Large-diameter particles do not follow the gas stream, but continue into a dead air space and settle.

Centrifugal collectors (fig. 16) use cyclone-type action to separate dust particles from the air. In a typical cyclone, the high velocity dusty air enters at a tangent. The centrifugal force created by the circular flow forces the dust particles toward the wall of the cyclone, where they fall into a hopper. These collectors are more expensive and more efficient in removing particulate than settling and baffle chambers.

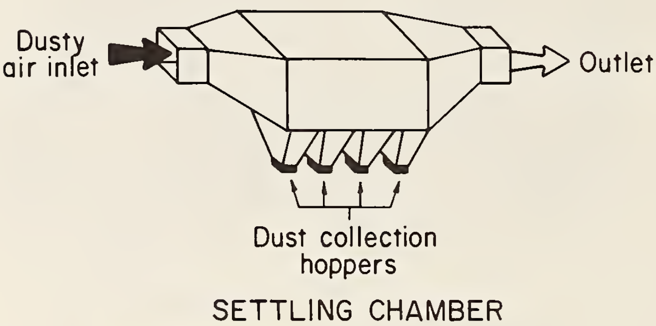

Figure 14.–Settling type drop-out chamber.

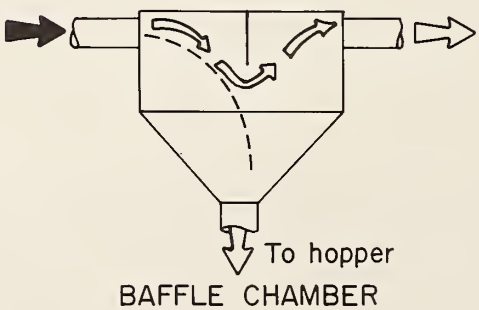

Figure 15.–Baffle type drop-out chamber.

CONTROL ROOM DUST

Control room dust is generally not a serious problem, except when the dust contains silica. Silica is not a problem in coal preparation plant control rooms, but it can be a serious health problem in many mineral processing plant rooms, especially because of the long-term, 8-h occupancy. Dust can also be detrimental to electrical equipment.

Wall- or window-mounted air conditioners admitting filtered outside air are adequate for control in most coal preparation plants. For mineral processing plants, high efficiency filters are strongly recommended. Minimum makeup airflows should be above several hundred cubic feet per minute even for small rooms (say 1,000 ft^3); this air should not be recirculated, but allowed to leak from the room. This will help insure a positive pressure within the room, and reduce dust infiltration. Conventional through-the-wall or window-type air conditioners should not be used for room pressurization; their makeup (fresh) airflow is usually too low for mineral processing plants.

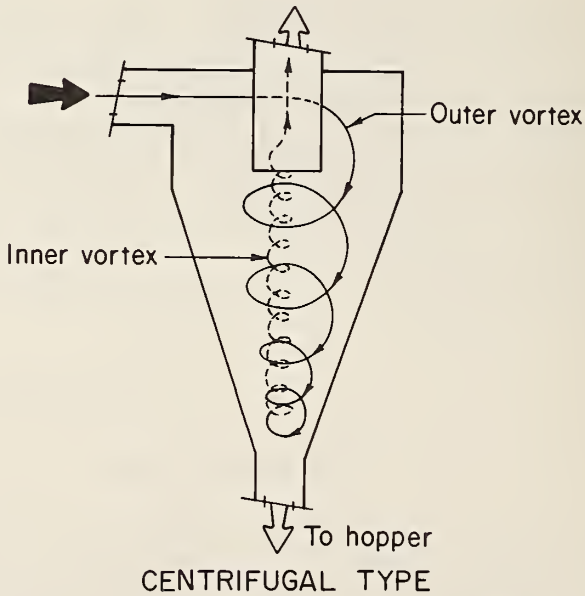

Figure 16.–Centrifugal type drop-out chamber.

CONCLUSIONS

Currently, about one-third of the coal preparation plants in the U.S. have excessive respirable dust concentrations in specific areas. Results from extensive work at mineral processing plants with dust problems indicate that dust concentrations are lower, but frequently compounded by silica and full-shift exposure. The primary solutions in both cases are essentially indentical and depend on dust sources, type, and concentration. In broad order of practicality and cost-effectiveness, these solutions are ventilation, baghouses, scrubbers, good housekeeping, and personal protection devices.

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